the zone to affect copepod egg production, egg viability or growth rate. Median chlorophyll *a* concentrations of 4.5-8.9 *ug*/l (range 3.2-12.3 *ug*/l) at the landward edge of the low salinity zone were above threshold values of 0.5-2.5 ug/l that limit copepod growth or egg production (Peterson et al. 1991). In contrast, the median (2.4-2.5 *ug*/l) and range (1.45-3.6 ug/l) of chlorophyll a concentrations at the seaward edge of the low salinity zone fell below or near these threshold values.

Chlorophyll a concentration, however, was probably not the best indicator of phytoplankton food availability in the LSZ. Copepods are size selective feeders and optimum predator to prey ratios calculated from the ratio of estimated spherical diameters (ESD) range from 9:1 to 33:1 for adults and copepodids (Hansen et al. 1994). For copepods in this study, optimum predator/prey ratios require phytoplankton ESD values in the range of 10.5-43.0 um for adults and 10-29 um for copepodids.

Many phytoplankton cells fell within the preferred ESD size range for adults and copepodids at station 1, where at least 45% of the cells were > 10 um (ESD) (Figure 5) and contrasted with station 6, where most of the ESD of most of the cells were < 10 um. Station 3 had some cells with the optimum ESD size in April, but few in May. These ESD values were reflected in the median predator/prey ratios which suggested adult and juvenile copepods had food available within the optimum size range at stations 1 and 3 in April (Figure 6). In May, only 10-25% of the ratios fell within the optimum size range at station 1.

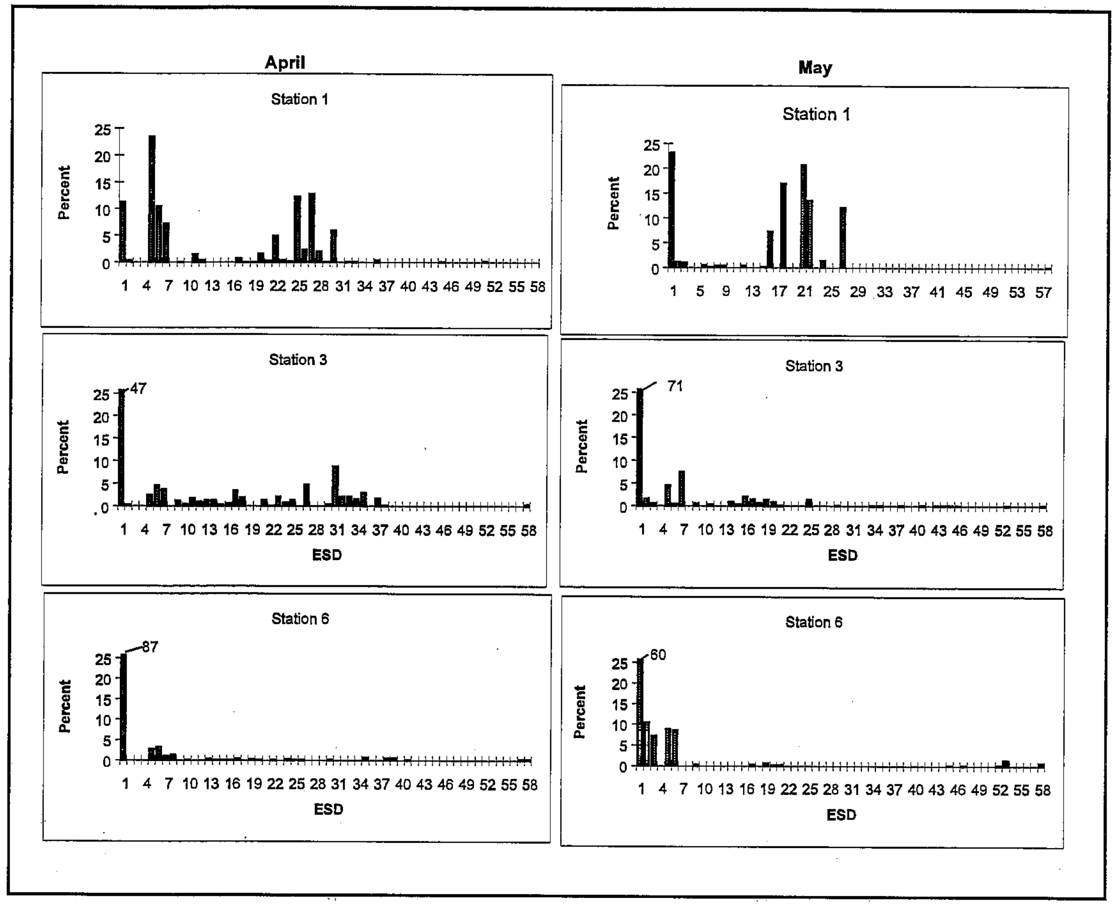

Figure 5
Percent of phytoplankton cells at different estimated spherical diameters (ESD). Optimum ESD for copepods in this study was 10-43 um.

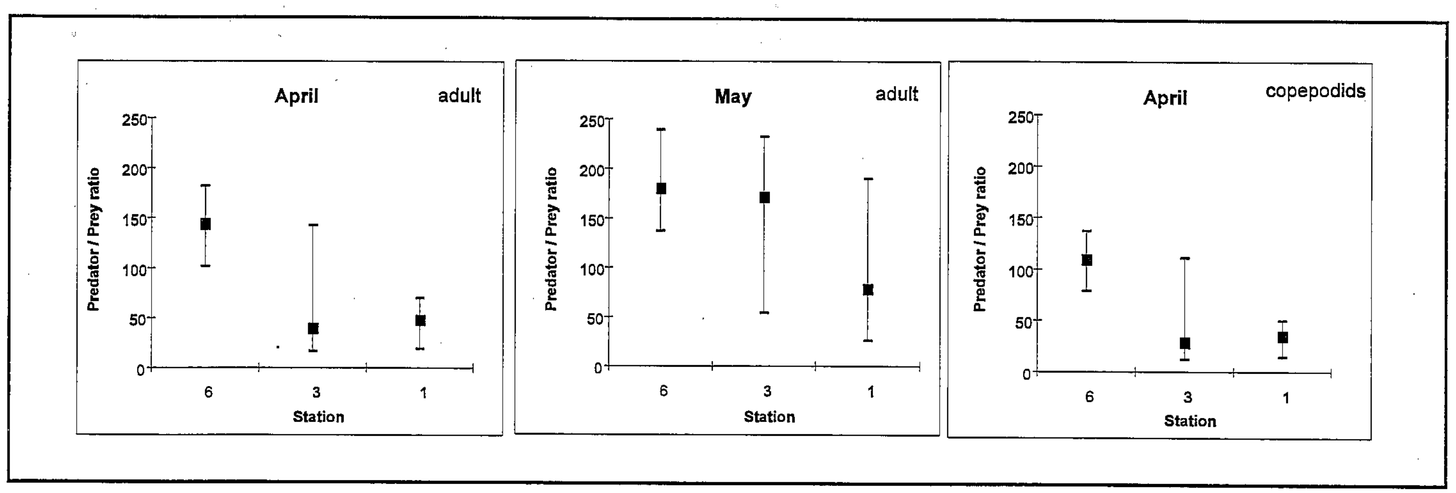

Figure 6
Median and 95th and 5th percentiles of predator/prey ratios at stations within the low salinity zone. Optimum ratios for copepods in this study were 9-33:1.

Summary

Abundant, large-diameter diatom cells and high biomass characterized the landward edge of the zone and contrasted with the seaward edge of the zone where ultraplankton composed of green and bluegreen algae were abundant and phytoplankton biomass was low. The center of the zone was more similar to the landward edge of the zone in April and the seaward edge of the zone in May. Although we do not know the actual copepod diet, the quality and quantity of phytoplankton food was probably good at the landward edge of the low salinity zone in both April and May and at the middle of the zone in April.

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Growth of Largemouth Bass in the Sacramento-San Joaquin Delta

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Introduction

Largemouth bass (*Micropterus salmoides*) were first introduced into California and the Sacramento-San Joaquin drainage in 1895 at Clear Lake and distributed to Sisson Hatchery (now inundated by Shasta Lake) (Dill and Cordone 1997). They were not noted in an extensive 1888–1889 survey of the Central Valley (Rutter 1907), but were sufficiently abundant to support a local "hook and line" commercial fishery in the Colusa area by 1908 (Dill and Cordone 1997). In the last 30 years, interest in largemouth bass fishing has increased rapidly, and they are now one the most sought after fish in the Delta.

Original introductions of largemouth bass were of the northern subspecies (*M. s. salmoides*), but between 1979 and 1983 the faster growing Florida subspecies (*M. s. floridanus*) was introduced into Clear and Folsom lakes, Lake Amador, and New Hogan Reservoir, all on delta tributaries. In all these lakes and reservoirs, genetic markers of the Florida strain largemouth bass had introgressed into the northern populations from relatively small introductions (Pelzman 1980), presumably because the Florida strain is faster growing and less vulnerable to angling. Sampling of largemouth bass in east delta dead-end sloughs in 1993 indicated that 21% of the 1992 year class and 30% of the 1993 year class contained Florida-strain alleles (unpublished data, CDFG).

This article reports largemouth bass lengths-at-age in the delta of fish collected during 1980–1984, before large-scale introgression of Florida strain alleles, and compares this growth with that of other largemouth bass in California. I also compare length at the end of the growing season in 1980–1984 with length in 1995 and 1997, after Florida-strain largemouth bass genes entered the delta population.

Methods

Largemouth bass for the 1980-1984 growth analysis were collected by electrofishing during three related surveys: (1) a delta-wide stratified random resident fish survey from May 1980 to April 1983, (2) a delta-wide monthly resident fish survey at 10 locations during 1984, (3) and a dedicated tagging survey during June and July of each year 1980 through 1984 which concentrated on east and central delta locations where largemouth bass were most abundant. Only largemouth bass > 200 mm fork length (FL) were tagged, so only fish in that size range were aged from the dedicated tagging. Fish ≤199 mm FL were subsampled for aging from the two resident fish surveys.

During 1995 and 1997, largemouth bass were collected in February and March during a resident fish monitoring study at 20 Delta locations. Largemouth bass ≤199 mm were available for aging only from 1997 sampling.

Length-at-age during the 1980s was estimated by back-calculating from annular growth marks and scale radii using the Frazier-Lee method (Carlander 1982). During the 1995 and 1997 sampling, length-at-age was determined by adding 1 to the scale age of fish captured at the end of the growing season. A similarly treated subset of the 1980s data (fish collected from October to March) was used for growth comparisons between the 2 time periods. All scales from 1980 to 1984 were read by two readers and those on which they disagreed were deleted from the data set. In 1995 and 1997, two readers aged all scales and disagreements were resolved by a third reader.

Results

During the 1980s, largemouth bass in the delta were the slowest growing low elevation population of largemouth bass reported in California (Table 1). With the exception of the high elevation (1,490 m) Big Sage Reservoir population, delta largemouth bass were smaller at all ages.

Differences in length at the end of the growing season between largemouth bass in the 1980s and 1990s were significant ($P < 0.05$) only at ages 1 and 7 (Table 2). Age 1 bass in 1997 were smaller than the comparable 1980–1984 group ($t = 2.41$, $P = 0.02$) and fish from 1995 and 1997 sampling at age 7 were larger than the similar aged fish in 1980–1984 ($t = 2.83$, $P = 0.04$).

Mean length of largemouth bass over 200 mm FL was not significantly different between decades ($t = 1.56$, $P = 0.06$) and the size distribution was also similar ($X^2 = 7.00$, $P = 0.72$) (Figure 1).

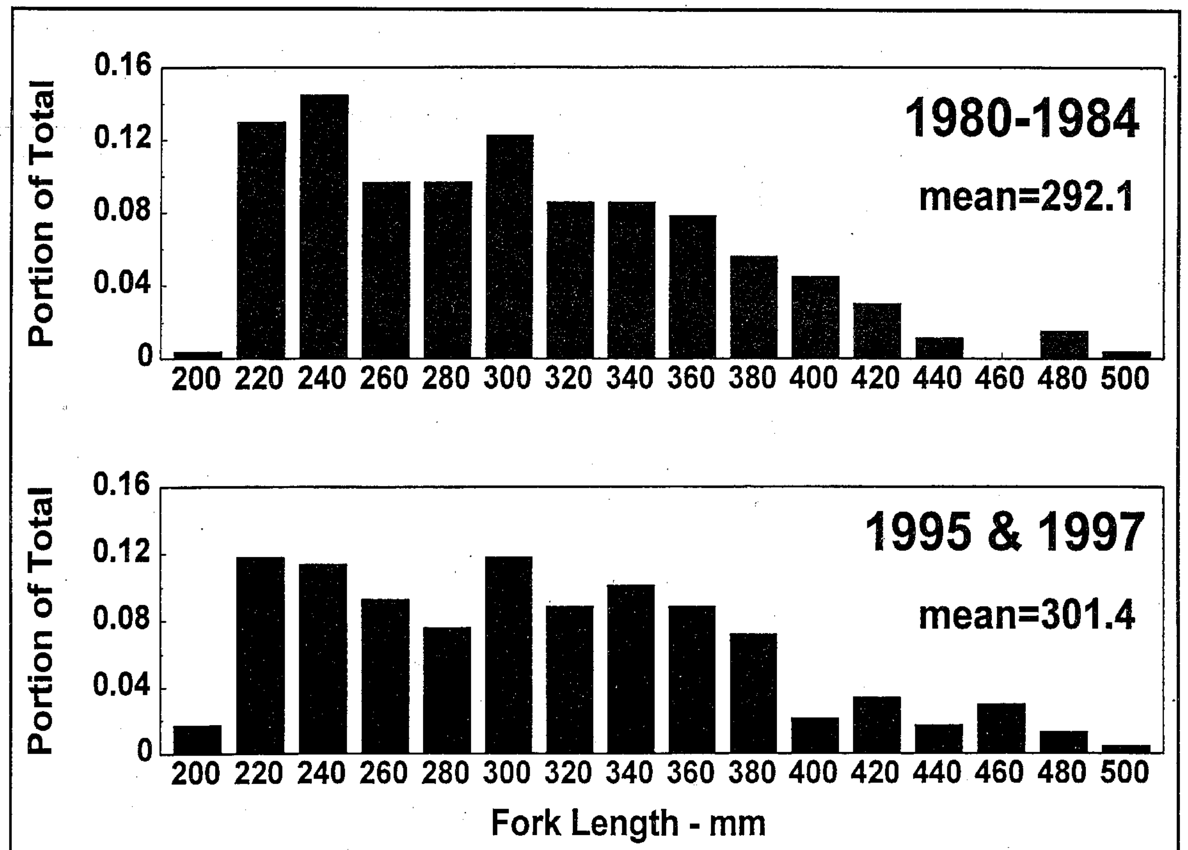

Figure 1
Length distributions of largemouth bass >199 mm in the Sacramento-San Joaquin Delta 1980-1984 and 1995 and 1997.

Discussion

Turner (1966) reported the relatively small size of centrarchids in the delta and attributed this small size to the high turbidity of delta waters, basing his conclusion on the findings of studies in turbid Oklahoma reservoirs. Miner and Stein (1996) found largemouth bass, which are active predators in clear water, become less effective ambush predators in turbid water and may encounter so little prey that they stop foraging.

Temperatures in delta waters may be suboptimal for largemouth bass growth for a longer period than shallow waters of reservoirs and small ponds. Largemouth bass grow at temperatures from 10.0 to 35.5°C, but the optimal temperature for growth is 27°C (Coutant 1975). This optimal temperature is seldom reached in the delta, but is common in small farm ponds and southern reservoir surface waters.

Diet and first-year growth of young-of-the-year largemouth bass is also temperature dependent. In many waters, early-spawned largemouth bass reach a length of 5–6 cm (when diet shifts from zooplankton to fish) soon enough during the first year to prey on young-of-the-year fishes, with consequent rapid first-year growth. In the delta, the optimal spawning temperature of 18.9–20.0°C (Coutant 1975) is reached too late in the season for most young largemouth to become piscivorous during their first year. This reduced first-year growth may carry over to subsequent years.

The impact of the introgression of Florida-strain genes into the delta largemouth bass population is not readily apparent in these growth data. The significant difference in length between 1980s and 1990s samples at the end of the first growing season (age

Table 1. Growth of Largemouth Bass in California Waters
All studies used back-calculated lengths at age from scale measurements.

Location and Citation	Back-calculated fork length (mm) at each annulus								
	I	II	III	IV	V	VI	VII	VIII	IX
Sacramento-San Joaquin Delta 1980–1984	88	185	260	315	353	383	410	421	
Northern largemouth bass[a]									
Big Sage Reservoir Kimsey and Bell (1955)	58	117	183	292					
Pine Flat Reservior Miller (1971)	99	213	308	361	414	515	541		
Millerton Reservior Miller (1971)	112	198	285	348	434	445	452		
Folsom Lake Therratt (1966)	142	264	325	368	402	431			
Suthurland Reservoir LaFaunce et al. (1964)	165	290	363	414	460				
El Capitan Reservior Bottroff and Lembeck (1978)	97	280	390	442	485	520			
Lake Havasu Beland (1954)	117	246	343	412					
Applegate Pond[b]	145	267	351	434	494				
Potter Pond[b]	120	244	327						
Reuter Pond[b] Schultz and Vanicek (1974)	126	268	339	382					
"Florida" largemouth bass[c]									
Hidden Valley Reservoir Week (1984)	176	281	361	427	478	519	559	580	616
El Capitan Reservior[d] Fast et al. (1982)	142	292	368	412	452	482	499	508	524
El Capitan Reservior Bottroff and Lembeck (1978)	150	324	399	448	517	560	586	593	630

[a] *Micropterus salmoides salmoides.*
[b] Low elevation (80-213m) farm ponds in western foothills of the Seirra Nevada east of Sacramento.
[c] *M. salmoides floridanus.*
[d] Judged hybrids of *salmoides* and *floridanus* subspecies on the basis of lateral line scale counts.

Table 2. Fork Lengths (mm) of Largemouth Bass Captured at the End of the Growing Season in the Sacramento-San Joaquin Delta, 1980-1984 and 1995 and 1997, with a Student's-t Comparison of Means at Each Age
Ages in this table are actual scale ages +1.

Period	Lengths and (number) at end of growing season							
	Age 1	Age 2	Age 3	Age 4	Age 5	Age 6	Age 7	Age 8
1980-1984	86(60)	179(75)	248(91)	311(60)	354(31)	380(11)	398(8)	431(3)
1995 & 1997	78(111)	178(93)	248(76)	314(67)	363(42)	389(17)	463(4)	453(3)
t	2.41	0.33	0.12	0.51	1.17	0.47	2.83	0.47
P	0.02	0.74	0.91	0.61	0.24	0.64	0.04	0.67

1, Table 2) may only reflect good growth conditions during 1996 (Note that fish <200 mm were only included in the aged sample in 1997, which is not directly comparable to the 1980s sample containing age-1 fish from four different years). Although older fish tend to be larger in the 1990s than in the 1980s, this difference was only significant at age 7 (Table 2).

Lower angler mortality rates may allow the present mixed strain largemouth bass to grow larger that the earlier northern-strain bass. Harvest rate of Florida-strain fish may be lower than for northern-strain bass because Florida-strain fish are less vulnerable to angling (Chew 1975). Harvest mortality rates of largemouth bass in the delta may also have decreased as the result of a movement towards a catch and release sport fishery. In the late 1980s, letters accompanying tag returns from delta largemouth bass occasionally mentioned that the tagged fish had been released after capture. This is more commonly reported now. As a result, a request for status of tagged fish (harvested or released) is included on postcards sent to anglers who return tag information. Data providing insight into these and other changes in mortality rates of largemouth bass in the delta is being accumulated and analyzed and will be reported in the future.

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CALFED Comprehensive Monitoring, Assessment, and Research Program

Randall L. Brown, DWR

On May 1, 1998, the CALFED Policy Group approved a $1.8 million proposal by the IEP, San Francisco Estuary Institute, and the U.S. Geological Survey to develop a comprehensive monitoring, assessment, and research program (CMARP) for CALFED. The program will be keyed to the CALFED implementation program, the six common program elements, mitigation, Category III monitoring, and will be a key part of the CALFED adaptive management strategy. The proposed program, including monitoring details (parameters, location, frequency, etc.) data management, decision support, and research, is due to CALFED in January 1999.

Since approved, CMARP has established an agency/stakeholder steering committee consisting of:

Margaret Johnston (SFEI - Co-chair)
Larry Smith (USGS – Co-chair)
Randy Brown (DWR – Co-chair)
Serge Birk (CVP Water Association)
Pete Rhoads (MWD)
Larry Brown (USBR)
Bruce Herbold (EPA)
Peter Stine (USGS)
Elise Holland (Bay Institute)
Fred Nichols (USGS)
Perry Herrgesell (DFG)
Tom Grovhoug (Sacramento Watershed)
Marty Kjelson (USFWS)
Bellory Fong (CALFED)
Laura King (Westlands WD)

CMARP also has designated Leo Winternitz (DWR) as Program Manager/Chief of Staff and identified agency staff to help carry out the work.

The CMARP effort is broken down into a series of five tasks, with Task 3 having several subtasks. The tasks are:

1. Refine Goals, Objectives, and Needs
2. Develop Conceptual Framework
3. Monitoring Program Design
4. Focused Research Program Design
5. Develop Institutional Structure

One of the first concrete steps in Task 2 was to convene a one and one-half day workshop to discuss the role of conceptual models in designing monitoring/research programs. The workshop was held on June 17 with about 40 attendees, including three invited speakers discussing similar programs outside California—Puget Sound, Chesapeake Bay, and South Florida. A draft workshop summary is being reviewed by the speakers and should be available for distribution by the end of July. Contact Leo Winternitz (lwintern@water.ca.gov) if you would like a copy.

Some general workshop conclusions are:

- Conceptual models have played key roles in monitoring research and restoration program development in Puget Sound, Chesapeake Bay, and South Florida, and have an important role in the Bay Delta.
- Conceptual models:
  - ➛are a representation of what we think we know and don't know, and are generally wrong because we don't know enough;
  - ➛are dynamic and evolve with increased understanding;
  - ➛take different forms, depending on the modeler, the purpose and the audience.
- The process of thinking through the model and discussing the model with peers is more important than the model itself.
- CALFED and local, state, and federal agencies are presently not making good use of explicit conceptual models in developing monitoring/restoration programs, adaptive management or communications with other scientists, managers, and the public.